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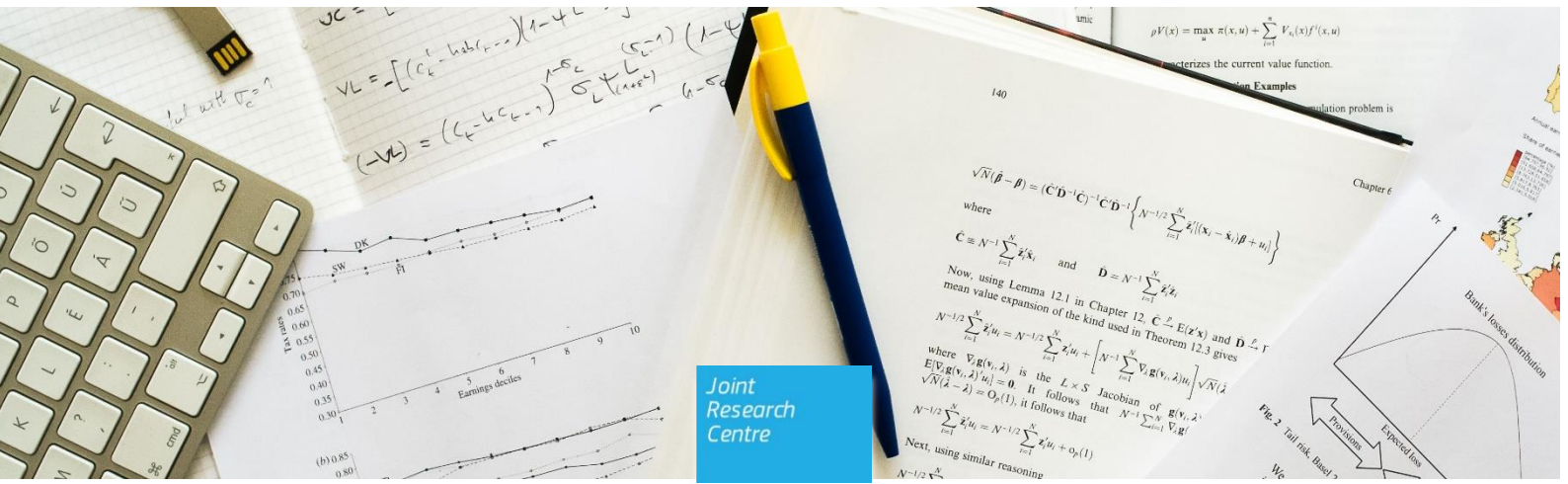

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Currency Matching and Carry Trade by Non-Financial Corporations*

Péter Harasztosi† Gábor Kátay‡

Abstract

The paper investigates firms' willingness to match the currency composition of their assets and liabilities and their incentives to deviate from perfect matching. Using detailed information at the loan contract level for the Hungarian non-financial corporate sector, the paper provides strong evidence to support the theory that currency matching plays a role in exporters' debt currency choices. However, natural hedging is not the primary motivation for firms to choose foreign currency: it explains less than 5 per cent of the overall new corporate foreign currency loans contracted by exporters and less than 2 per cent of the aggregate new foreign currency bank loans. Besides hedging, our results suggest that both carry trade and diversification strategies are relevant factors in firms' currency-of-denomination decisions.

Keywords: borrowing decisions; currency mismatch; carry trade; financial crisis
JEL classification: G01; G11; G32; F31; F34

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1 Introduction

Matching debt payments to expected foreign currency (FX) revenues is a natural way to mitigate the adverse effects of foreign exchange risk exposure of exporting firms. Currency mismatch occurs when firms' assets and liabilities are denominated in different currencies. Financial stability concerns typically arise when firms' net FX-denominated liabilities are greater than their net FX-denominated cash flows, i.e. when firms borrow "too much" in FX relative to their export revenues. As a result, when domestic currency depreciates, firms with currency mismatch are likely to experience adverse balance sheet effects as the negative effect of the rise in FX-denominated liabilities expressed in local currency usually outweighs the traditionally assumed positive competitiveness effect (Eichengreen et al. (2007)).

This paper explores corporate borrowers' choice between the local currency and several possible foreign currencies in the situation that the market interest rates in one or several foreign currencies are lower than that of the local currency. In particular, we investigate firms' willingness to match the currency composition of their assets and liabilities and their incentives to deviate from perfect matching. Using detailed information at the loan contract level for the Hungarian non-financial corporate sector, we construct a theory-consistent matching measure and test its influence on firms' choice of currency denomination of borrowings. In doing so, this paper is the first to provide direct evidence to support the role of matching incentives in firms' debt currency choice. The relative importance of matching motivation versus other factors such as the interest rate differential is also addressed.

The debate about the importance of firms' currency mismatches and the adjustments following an unexpected exchange rate depreciation was particularly intense following the Latin American "Tequila" crisis. In these countries, the perceived security of the exchange rate peg encouraged liability dollarisation, while abandoning the peg resulted in a sharp depreciation of the home currencies. Due to the extensive dollarisation of firms' balance sheets and widespread currency mismatches, the weakening of the exchange rate and the implied increase in firms' debt burden in local currency terms forced firms to adjust their balance sheets, which translated into lower investment activities, declining production and, in many cases, liquidation proceedings. (see e.g. Krugman (1999) or Aghion et al. (2001)). Later, a similar process took place in Asia during the financial crisis of 1997-98 and in several Central and Eastern European (CEE) countries following the start of the current crisis.

To test for the existence of matching motivations in firms' debt currency choice, existing empirical studies usually relate the share of FX debt to a proxy for the sensitivity of firms' profits to exchange rate fluctuations and other firm-specific or macroeconomic variables. The earliest studies investigated the currency-of-denomination decision of large US firms (Allayannis and Ofek

(2001); Kedia and Mozumdar (2003)) and Finnish firms (Keloharju and Niskanen (2001)) and found that firms with higher export shares (or a larger share of total assets held abroad) hold more FX-denominated debt in order to hedge their increased foreign exposure. A considerable number of studies on emerging markets – many of which were published in a special issue of the *Emerging Market Review* (vol. 4 no. 4) – point to the same conclusion.[1] These papers follow a similar reduced form estimation method in which the identification relies on the export share variable or on an indicator of tradability (dummy variable indicating whether the firm belongs to the tradable sector) to show that exporters or firms producing tradable goods are more likely to carry foreign debt. The coefficient of these variables is usually positive and – with the exception of the Argentinian and Brazilian results – significantly different from zero. The authors conclude that firms tend to match the currency composition of their liabilities with the ex-ante sensitivity of their revenues to the real exchange rate.

On the other hand, the role of the interest rate differential and thus carry trade behaviour is often put forward as an explanation for dollarisation in macro studies. Rosenberg and Tirpak (2009) examine the determinants of euroisation and swissfrancisation in the new EU Member States and find that the interest rate differential is a robust explanatory variable of cross-country differences. Basso et al. (2011) find that the interest rate differential is a significant driver for the dollarisation of both loans and deposits.

This paper highlights and addresses three important shortcomings of the existing empirical literature. First, the existing evidence that exporting firms tend to borrow more in FX does not provide direct proof for currency matching. Export revenues are only half of the story, the appropriate measure for testing matching considerations between assets and liabilities should include both export revenues denominated in FX and FX debt repayments. For instance, a firm that increases its FX debt to a point that the expected export revenues do not fully cover its debt repayments is exposed to a similar exchange rate risk as non-exporters with FX liabilities in their balance sheets. Similarly, it is safe for a firm with a relatively low export share to incur debt entirely in FX as long as its export revenues are higher than or equal to its debt repayment obligations.

Second, unobserved firm heterogeneity is rarely taken into account. Comparing two distinct groups of firms, (larger) exporters and (smaller) non-exporters, which are probably different in many respects, and identifying firms' matching incentives from cross-sectional variation does not provide direct evidence for matching. If the choice of currency denomination of the debt is a result of an optimisation process, the same firm in different circumstances should make different

[1]The special issue starts with a summary of Galindo et al. (2003) that collects results and findings from existing literature. Existing studies on emerging markets cover Argentina (Galiani et al. (2003)), Brazil (Bonomo et al. (2003); Janot et al. (2008)), Chile (Benavente et al. (2003), Cowan et al. (2005); Fuentes (2009)), Colombia (Echeverry et al. (2003)), Mexico (Pratap et al. (2003); Gelos (2003); Martinez and Werner (2002)) Peru (Carranza et al. (2003)), Lebanon (Mora et al. (2013)) and several East Asian (Allayannis et al. (2003)) and Latin-American economies (Kamil (2012)) .

choices. That is, the identification of matching incentives is possible only once firm fixed effects are controlled for.

Third, there is as yet no clear understanding of which effect dominates in a firm's decision to incur FX-denominated debt. Only a few studies have concentrated on both natural hedging and carry trade incentives. Among the few exceptions are the contributions by Keloharju and Niskanen (2001) and Brown et al. (2010), who confirm that both matching and carry trade motives are present in firms' currency choice. By examining Finnish and Bulgarian firms, the authors find that exporters are more likely to request FX loans, while firms also tend to choose FX when the interest rate differential between FX and domestic currency is higher than average. A descriptive study by Endresz et al. (2012) also suggests that both matching and carry trade are relevant factors: FX debt is mostly concentrated among larger, exporting firms, but many small non-trading firms also take out FX loans in Hungary. The relative importance of the two factors is addressed only in Brown et al. (2011). The authors find that FX borrowing is more strongly related to firm-level FX revenues than it is to country-level interest rate differentials, which leads them to conclude that speculation is not the key driver of firms' currency choice.

The recent Hungarian experience of FX indebtedness together with a newly available collection of matched administrative datasets – which includes financial reports of all Hungarian firms, monthly export revenues and import expenditures, information on all corporate loan contracts and on the credit provider – provide a valuable opportunity to reassess the determinants of firms' borrowing decisions in the situation that they have access to FX loans. In Hungary, as in the majority of CEE countries, the post-socialist economic transition was fuelled in part by heavy borrowing from Western banks and easy access to FX-denominated loans through local branches. For about a decade before the crisis, FX-denominated loans became widespread among both households and firms. As long ago as 2005, more than 45 per cent of the outstanding corporate loans were denominated in FX (see Appendix A for details).

We restrict our analysis to exporting firms, for which natural hedging motivation might be relevant. Our identification strategy relies on the intuition that if currency matching is a relevant factor, the firm is more (less) likely to incur new FX-denominated debt when its expected export revenues exceed (are lower than) its FX debt reimbursement obligation during a given period of time. This yields a binary dependent variable model in which the probability of choosing FX is related to a currency matching measure defined as the difference between the firm's export revenues and its debt repayment obligations denominated in FX. Using both fixed effects (Chamberlain (1980)) and correlated random effects (Mundlak (1978)) logit models, our estimation strategy takes into account firm-level fixed effects by conditioning on (fixed effects model) or controlling for (correlated random effects model) how many times FX has been chosen by the firm. The parameters of interest are identified by using information on the timing of the choice, i.e. when the FX or the

local currency is chosen. As a second step, a more accurate matching measure yields a mixed logit specification (Train (2003)) in which separate but correlated equations for two possible FX alternatives – corresponding essentially to euros (EUR) and Swiss francs (CHF) – are estimated simultaneously.

We then use the estimated model to perform a counterfactual analysis. To isolate the effects of natural hedging motives on the aggregate corporate FX debt share, we "switch off" the effects of currency matching on firms' debt denomination choice by setting the coefficient of our matching measure to zero for all firms and for all choice occasions and we predict the counterfactual currency shares of newly contracted corporate loans in the absence of hedging motives.

The coefficient of the matching variable being positive and highly significant across all specifications, our results provide strong evidence to support the role of natural hedging motivation in firms' currency choice. Matching motivation is even stronger for foreign companies and for long-term loans. However, we do not find evidence that the current financial crisis has altered firms' matching incentives.

Even though matching is a robust determinant of firms' currency choice, our simulations indicate that natural hedging is not the primary motivation for firms to choose FX: it explains only less than 5 per cent of the overall new corporate FX loans contracted by exporters. Assuming that non-exporters do not take natural hedging considerations into account, currency matching is responsible for less than 2 per cent of the aggregate new FX bank loans during the period considered.

In addition, our results indicate that firms with a higher probability of choosing EUR also have a higher probability of choosing CHF. The benefits of holding both EUR and CHF debt thus seem to outweigh the advantage of consistently choosing one (the preferred) FX relative to the other, which can be interpreted as firms placing higher value on diversification than on fully exploiting perceived arbitrage (carry trade) opportunities, if any, between foreign currencies.

After briefly presenting the data used for our analysis (Section 2), we describe the characteristics of new corporate loans in Hungary (Section 3). Section 4 develops the empirical framework. The econometric analysis of firms' currency choice is presented in Section 5, then the counterfactual simulation results are shown in Section 6. The final section concludes.

2 Data

To assess the determinants of currency-of-denomination choice of Hungarian non-financial corporations, we use four matched administrative datasets. We principally rely on the credit register (KHR) database containing the universe of all new and already existing corporate loan contracts from Hungarian financial institutions between 2005 and 2011. The dataset provides information on

contracts' starting date, duration, value, denomination and type of providers. Providers are banks, saving banks and other financial companies.

For the detailed description of the KHR dataset, see Endresz et al. (2012). We deviate from the construction of the dataset described in Endresz et al. (2012) in one important aspect. To focus on currency choices, we collapse the loan contacts denominated in the same currency and signed by the same company in the same month. That is, if a firm takes out two loans in the same currency in the same month, we combine the corresponding contracts to form a single contract with the sum of the two loans and a duration defined as the weighted mean of the duration of the two original loans. As a result, the average annual number of new contracts falls to about 70 per cent of the original, while the total amount of outstanding debt in each month and the aggregate monthly flow of debt service expenses remain unchanged.

The credit register is then merged with the yearly panel database of corporate tax returns. The database is provided by the Hungarian tax authorities (NAV) and contains balance-sheet and income statement information for all double-entry book-keeping firms operating in Hungary. We use variables that are likely to affect firms' demand for credit and the choice of its currency denomination, such as employment, foreign ownership, capital, liquidity, total assets and profitability measures.

Although the NAV dataset contains the export share of sales, we collect additional trade information from the Hungarian Central Statistical Office on trade behaviour. We merge the statistics on exports and imports calculated from the monthly reports on commodity trade to Extra- and Intrastat for the universe of direct trading firms in Hungary. The monthly frequencies enable us to calculate, for example, the export revenues during the 12 months preceding the signing of the loan contract.

Finally, we extend the dataset by including information on the credit provider. Following the methodology proposed by Ongena et al. (2014), we match a list of bank characteristics – such as foreign ownership, total assets, capital ratio, liquidity ratio, return on assets and doubtful loan ratio – to the contract-firm level dataset.

The resulting dataset, which covers the years 2005-2011, includes 129,066 firms and each year, on average, about 42,700 firms take out loans. Over the period, the average annual number of new contracts stands at about 65,000. It rises from about 77,000 to a little over 82,000 just before the start of the crisis. After 2008, it drops to below 50,000. When we focus on exporting firms only, we observe 8,079 firms in all, out which, each year, about 3,000 take out loans. On average, we observe 6,700 new loan contracts each year in a declining trend starting from 8,300 in 2005 and ending in 4,900 in 2011. On average, 68 per cent of the new contracts taken out by exporting firms are denominated in local currency (Hungarian Forint, HUF).

3 Characteristics of new corporate loans in Hungary

Breaking down the composition of debt currencies by maturity and firm characteristics reveals that smaller bank loans – expressed as a percentage of firms' total assets, presumably for continuing operations or for financing replacement investment – were mainly denominated in local currency, while FX loans were primarily used for financing larger projects (Figure 1). We arrive at the same conclusion by comparing short-term (less than a year) and long-term contracts separately: comparing subfigures 1(a) and 1(b) shows that, in the case of short-term contracts, about two-thirds of the overall underwritten sums are in HUF , compared with about half for long-term contracts. In line with previous empirical findings (Section 1), Figure 1 also shows that export-oriented firms are more likely than other firms to take out FX loans. Moreover, exporters tend to prefer EUR-denominated loans. Given that the euro area accounts for an overwhelming share of Hungarian exports, these figures suggest that matching motives are likely to play a role in explaining firms' FX choices. At the same time, the FX debt exposure of non-exporting firms and the relatively large share of CHF loans in firms' debt portfolio also suggest that the share of unhedged loans was (and still is) substantial in Hungary.[2]

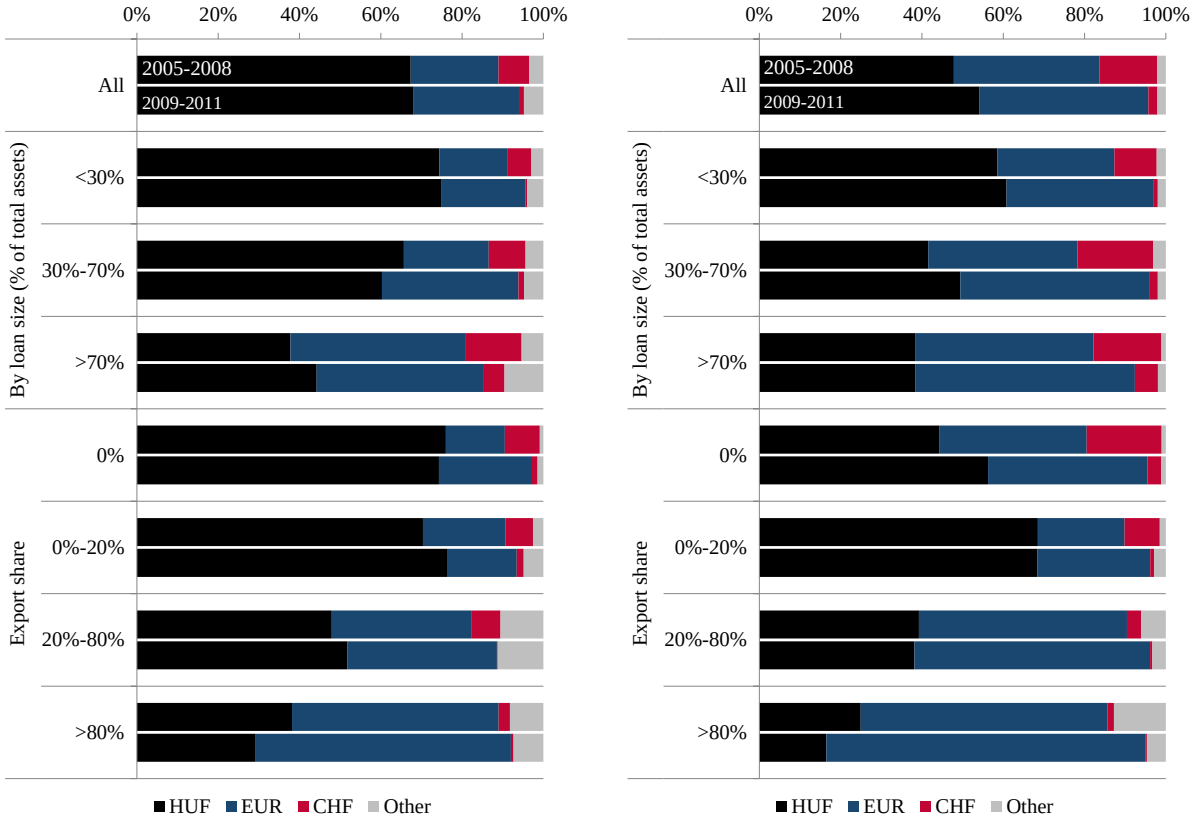
Vonnak (2015) points to the same conclusion. Comparing CHF and EUR borrowers in the lending boom and during the crisis, the author finds that the latter are more likely to be bigger, foreign-owned and export-oriented firms, while the former are more likely to be non-exporting firms and firms with weaker balance sheets and a higher default probability even during the pre-crisis period. The descriptive study in Endresz et al. (2012) also reports that FX debt is mostly concentrated among larger and more productive and most likely multinational firms, but a significant share of domestic non-trading firms also took out FX loans. Moreover, a survey conducted by Bodnar (2009) on the FX indebtedness of Hungarian companies suggests that financial hedging is practically non-existent. A significant share of the firms simply ignore exchange rate risks as either they are unaware of risk management techniques or such techniques are perceived as expensive, complicated and ineffective. Driven by the attractive foreign interest rates, these firms expose themselves, unwittingly or not, to risks associated with exchange rate depreciation.

In this paper, we focus on exporters, as natural hedging is irrelevant for non-exporting firms. Tables 1 and 2 show whether the simultaneous presence of several currency denominations among exporting firms results from the aggregation of distinct individual currency choices or from firms holding multiple currencies in their debt portfolio. The first row of Table 1 shows that about one-third of exporters took out both HUF and FX loans during the pre-crisis period. When only firms with more than one loan contract are taken into consideration, this figure climbs to 53 per cent. That is, a large proportion of firms do not stick to one single currency but choose – presumably

[2]Note that the share of exports to Switzerland in total exports was only 1.3 per cent in 2008 and less than 1 per cent in 2015 (source: Eurostat Comext database)

strategically – the currency denomination of their loan on all choice occasions. These firms provide useful within-firm variation for our econometric analysis.

Figure 1: Characterisation of long- and short-term contracts



(a) Short-term contracts

(b) Long-term contracts

Notes: The left-hand panel describes short-term loans and the right-hand panel describes long-term loans. The Table shows the shares of new loans by denomination. A panel consists of three main blocks. The first describes all loans, with separate bars for the periods 2005-2011 and 2009-2011. The second differentiates between three loan sizes: below 30%, between 30 and 70% and above 70% relative to total assets. The third block differentiates loans by firms' export shares. HUF stands for Hungarian Forint (local currency), EUR is euro and CHF is Swiss francs.

To determine if there is a clear pattern in the order of firms' currency choice, the second and third rows of Table 1 display the distribution of firms by their choice of currency denomination of their new loans subscribed after their first domestic or FX-denominated loan contract. The third row is particularly interesting, as it disproves the idea that limited access to FX credit is the major source of within-firm variation. In this case, (risk-neutral) firms previously indebted solely in HUF that access FX loans for the first time during our sample period would never switch back to the

local currency. However, more than 76 per cent of firms with an existing FX debt in their balance sheet will later sign at least one HUF-denominated loan contract. In the empirical part of this paper, we will examine whether firms' currency choice, and in particular the timing of a specific choice, is purely arbitrary or whether it is governed by explicable rationality.

Table 1: Number of firms by the currency denomination of their contracts (exporters only)

	one contract		more than one contract			total
	HUF	FX	only HUF	only FX	both	
total number of firms	3 050	784	2 923	449	3 778	10 984
	(27.8%)	(7.1%)	(26.6%)	(4.1%)	(34.4%)	
only contracts after the first HUF loan	1 284	292	1 876	199	2 711	6 362
	(20.2%)	(4.6%)	(29.5%)	(3.1%)	(42.6%)	
only contracts after the first FX loan	109	292	163	646	2 710	3 920
	(2.8%)	(7.4%)	(4.2%)	(16.5%)	(69.1%)	

Notes: The table shows the number of exporting firms with at least one loan contract underwritten between 2005 and 2011, distributed according to the currency denomination of their loans. The table differentiates between single-contract and multi-contract firms. The first row shows all contracts. The second and third rows show only contracts underwritten after the first Hungarian Forint (HUF) loan and after the first foreign currency (FX) loan only, respectively. Thus, the last two rows show data for multi-contract firms only.

Table 2: Number of firms with more than one FX loan (exporters only)

	Only EUR	Only CHF	Only other FX	EUR & CHF	EUR & other	CHF & other	EUR, CHF & other
Two FX loans	464	207	20	153	15	5	
	(53.7%)	(24.0%)	(2.3%)	(17.7%)	(1.7%)	(0.6%)	
Three FX loans	256	81	8	134	15	5	6
	(51.3%)	(16.2%)	(1.6%)	(26.9%)	(3.0%)	(1.0%)	(1.2%)
Four or more FX loans	694	74	18	530	109	8	65
	(48.4%)	(5.2%)	(1.3%)	(37.0%)	(7.6 %)	(0.6 %)	(4.5%)

Notes: The table shows the numbers of firms with two (first row), three (second row) or four or more foreign currency (FX) loans (third row) contracted between 2005 and 2011, distributed according to the currency denomination of their contracts. EUR is euro and CHF is Swiss francs.

Table 2 focuses on exporting firms with more than one FX-denominated loan contract. When only firms with two FX-denominated contracts are taken into consideration, about 20 per cent of these firms contracted loans in two foreign currencies, mainly EUR and CHF. The share of firms with several foreign currencies in their debt portfolio increases with the number of FX loans

contracted: 32 per cent of firms with three FX loans and almost 50 per cent of firms with four or more FX loans prefer to diversify their FX liabilities rather than always choose the same FX.

4 Identification strategy

Using monthly panel data at the contract level, firms' currency choice is studied using discrete choice models. If currency matching is a relevant factor that firms consider in their choice of currency denomination of their bank loans, the firm is more (less) likely to incur new FX-denominated debt when its expected export revenues exceed (are lower than) its FX debt reimbursement obligation during a given period of time. This intuitive assumption is consistent with the minimum variance portfolio (MVP) theory, a framework often used in the literature to model firms' decisions about the currency-of-denomination of their debts (see e.g. Thomas (1985); Ize and Yeyati (2003); Luca and Petrova (2008); Bleakley and Cowan (2009); Basso et al. (2011)). According to the MVP approach, risk-averse investors seek, on the one hand, to minimise their exposure to exchange rates deterioration and, on the other hand, to maximise their expected returns by exploiting (perceived) arbitrage opportunities between funding currencies. The resulting optimal debt portfolio can be represented as the sum of a standard Markowitz portfolio (the speculative component) and a hedge term represented by the perfect matching portfolio. The perfect matching portfolio is achieved if the firm's expected export revenues fully cover its FX debt repayment obligations.[3]

To test natural matching considerations, we rely on a currency matching measure defined as the difference between the firm's export revenues denominated in foreign currency c and its debt repayment obligations in the same foreign currency (without considering the actual loan contract). More formally, $M_{ijct} = (X_{ict} - L_{ij'c,t+1})/A_{it}$, where M_{ijct} is the matching measure for firm i and contract j in currency c subscribed in time t, X_{ict} denotes the firm's past 12-month average export revenues invoiced in currency c and $L_{ij'c,t+1}$ is the firm's monthly average debt repayment obligation over the next 12 months in the same currency c stemming from all existing contracts j' other than the actual loan contract j. The mismatch measure is normalised by total assets A_{it}.

Note that if $L_{ij'c,t+1} = 0$, i. e. if the firm does not hold FX debt at the time when the decision on the currency denomination of the new loan is made, our matching measure is similar to simply using export share as a proxy for matching incentive. However, previous FX debt is an important factor that firms are likely to take into account: on about 60 per cent of all choice occasions in our sample of exporting firms, the firm already has an existing FX contract.

[3] see Appendix B for a simple MVP model that illustrates the effect of exchange rate fluctuations on firms' choice between the local currency and several possible foreign currencies.

We use past values for X_{ict} – just as for all other explanatory variables explained later – to avoid simultaneity. In practice, the decision on the currency denomination of the debt, the export strategy and the invoicing currency of export sales might be taken simultaneously by the firm. First, firms might adjust their exports at the intensive margin or possibly reorient their exports towards a specific destination in response to having access to foreign currency loans with lower interest rates. Second, the choice of the currency denomination of the debt might also impact the invoicing currency of firms' export sales. The currency invoicing literature argues that the choice of invoicing currency is influenced by several factors, such as the price-sensitivity of demand, the exchange rate and relative monetary volatility (see e.g. Giovannini (1988); Donnenfeld and Zilcha (1991); Friberg (1998); Devereux et al. (2004)) or the trading partners' relative bargaining power (Bacchetta and van Wincoop (2005); Friberg and Wilander (2008)), but also by firms' desire to hedge marginal costs due to the use of imported inputs or FX debt (Goldberg and Tille (2008); Chung (2016)). That is, it may be optimal for firms to invoice their exports in currency c if their liabilities are in the same foreign currency. Using past values for export revenues minimises the potential simultaneity bias. Accordingly, the matching measure is negative if and only if the firm is already in mismatch without considering the actual loan contract, simultaneous or future decisions on export orientation or the invoicing currency.[4] Nevertheless, as a robustness check, we also performed our econometric analysis using future 12-months average export revenues.

In our empirical specifications, firms' decisions are modelled as a probabilistic choice problem. In line with the theoretical predictions of optimal currency shares stemming from the MVP approach, the extent of deviation from the perfect matching portfolio is influenced by firms' risk perceptions, risk attitudes and expectations about the future paths of interest rates and exchange rates, all of which are subjective assessments that investors believe in and which differ from firm to firm. These measures are captured by a set of observed time varying firm-level and bank-level characteristics (Z_{it-1}), a currency-specific firm-level unobserved parameter (a_{ic}) that represents the effects of firms' unobserved attributes and a random component ε_{ijct} assumed to follow an i.i.d. logistic distribution. Under these assumptions, the conditional probability that currency c is chosen is given by (see McFadden (1974)):

$$P(y_{ijt} = c \,|Z_{it-1}, M_{ijct}, a_{ic}, \forall c) = \frac{\exp(a_{ic} + Z_{it-1}\Omega_c + \phi_c M_{ijct})}{1 + \sum_{c'=1}^{C} \exp(a_{ic'} + Z_{it-1}\Omega_{c'} + \phi_{c'} M_{ijc't})} \tag{1}$$

[4]See also Section 4.2 for a more detailed discussion on the invoicing currencies of Hungarian exports.

where y_{ijt} is the observed outcome.[5] Parameters ϕ_c capture firms' willingness to match the currency composition of their incomes and liabilities to avoid exposure to exchange rate risk. If matching incentives matter, we expect that a firm is more (less) likely to take out an FX loan when M_{ijct} is high (low), so ϕ_c is expected to be positive. The baseline category is the local currency (HUF) with the probability of it being chosen given by $P(y_{ijt} = \text{HUF}\,|Z_{it-1}, M_{ijct}, a_{ic}\forall c) = 1/(1 + \sum_{c'=1}^{C} \exp(a_{ic'} + Z_{it-1}\Omega_{c'} + \phi_{c'} M_{ijc't}))$.

4.1 The binomial case

In our first specification, we estimate the impact of the matching measure on the probability of signing an FX loan contract rather than one in local currency. For each month, all foreign currencies are collapsed together. The set of possible alternative choices is thus limited to $c = \{\text{fx}\}$ and HUF is the baseline category. The matching indicator is constructed using total export revenues and total debt repayment obligations all foreign currencies combined. In this case, equation (1) reduces to the binomial logistic function (and subscripts c can be dropped).

The main econometric difficulty is dealing with unobserved heterogeneity (a_i), in particular its relationship with the covariates. Explicitly including dummies for the fixed effects and estimating the equation using standard logit yields consistent estimates only if the time dimension tends to infinity. For fixed time dimension (T), the unconditional maximum-likelihood estimator of the incidental parameters is inconsistent, which in turn contaminates the rest of the coefficients. The inconsistency arises because the number of incidental parameters increases without bound, whereas the amount of information about each incidental parameter remains fixed (Neyman and Scott (1948)). To resolve the endogeneity issue due to the presence of incidental parameters, Andersen (1970) and Chamberlain (1980) propose an estimator of the structural parameters by conditioning the likelihood function on minimal sufficient statistics for the incidental parameters and then maximising the conditional likelihood function. In the logit case, such statistics can be $\sum_{t=1}^{T} y_{ijt}$. Intuitively, the minimal sufficient statistics capture all possible information about time-invariant firm-level parameters that influence how many times an alternative has been chosen by the firm. Conditional on this, the parameters of interest are identified by using information on when a specific alternative is chosen.

[5] McFadden derives the analytical expression for the selection probabilities in eq. (1) using the axiom of independence of irrelevant alternatives (IIA) introduced by Luce (1959), which states that the relative odds of one alternative being chosen over a second one is independent of the presence or absence of any other alternatives. Under this assumption, the relative odds of choosing a specific foreign currency rather than the local currency can be determined as if no other foreign currency alternative were available. Accordingly, the probability of choosing foreign currency c is given by $P[a_{ic} + Z_{it-1}\Omega_c + \phi_c M_{ijct} > \varepsilon_{ijct}]$. With multiple foreign currencies, the system of independent logit equations leads to the expression for the probability that firm i chooses currency c given by eq. (1). As explained later, the strong assumption of IIA can be relaxed by specifying, for example, a mixed logit model.

The principal advantage of Chamberlain's conditional (fixed effects) logit is that it requires no assumption on a_i, hence it allows for any form of correlation between the fixed effects and the regressors. However, the estimation method has several drawbacks. First, since the parameters are identified using within-firm variation, only firms that change state (i.e. those indebted in more than one currency) are considered. Although the sample of firms with bank loans denominated in more than one currency is large enough for asymptotic results to be valid (see Table 1), the incomplete coverage of firms might be a problem if one wants to draw inferences for the whole population or the excluded sub-population. Second, the incidental parameters are not identified and their distributions are unrestricted, which is necessary to calculate quantities of interest such as marginal effects and probability projections. Finally, the conditional logit exhibits the unpleasant property of independence of irrelevant alternatives (IIA): adding another alternative (another foreign currency, in our case) does not affect the relative odds between the two alternatives previously considered.[6]

An alternative approach is to treat the unobserved heterogeneity as random effects. Obviously, the extreme assumption of no-correlation between a_i and the covariates is necessarily violated. Indeed, a more risk-averse firm is, *ceteris paribus*, less likely to carry FX debt and its export revenues are thus more likely to exceed its FX debt repayment obligations. Mundlak (1978) and Chamberlain (1982) relax this crucial random effects assumption by allowing the unobserved effects to be correlated with the covariates following a linear specification. In Mundlak's specification, $a_i = \bar{X}_i\xi + \omega_i$, with $\bar{X}_i$ being a row vector of the time-average of all exogenous covariates (Z_{it-1} and M_{ijt}) and ω_i being a normally distributed error term. Chamberlain proposes a more general form by including the vector of all explanatory variables across all time periods: $a_i = \sum_{t=1}^{T} X_{it}\xi_t + \omega_i$. In both cases, the additional explanatory variables included in the model allow us to control for the correlation between a_i and the covariates while using a standard random effects estimator. The intuition behind the identification is in fact similar to that of the conditional logit estimator. In this paper, we employ both the conditional logit model and the correlated random effects logit model with Mundlak's correction to estimate the determinants of foreign currency choice.

4.2 The multinomial case

To estimate the discrete choice model with all available alternatives, a separate mismatch indicator has to be constructed for all foreign currencies. Unfortunately, export destinations (or, which would be even better, export invoicing currencies) are not specified in the database that we use. Based on the relative importance of the different currencies in the Hungarian external trade and the aggregate currency composition of the loans, it is reasonable to assume that the main "matching currency" that firms may consider to hedge exchange rate risks on exports is EUR, while CHF is the principal

[6]See e.g. Wooldridge (2010). This property is irrelevant if only two options are taken into consideration: foreign currency and local currency. However, in the multinomial case, the model generates implausible substitution patters.

"speculative currency" and irrelevant for hedging purposes. Indeed, the euro area is Hungary's major trading partner: it accounts for 57 per cent (in 2008) of the country's total exports, whereas less than 2 per cent go to Switzerland.[7] Moreover, the EUR is also widely used as vehicle currency: according to the most recent data available, for 2004, 84.8 per cent of total Hungarian exports are invoiced in EUR (see Kamps (2006)). The second most important invoicing currency is the US dollar, accounting for 9.6 per cent of Hungarian export revenues. The HUF accounts for no more than 2.3 per cent and, consequently, all other currencies account for only 3.3 per cent.

We therefore rely on the simplifying assumption that all export revenues are invoiced in EUR in all firms. The other foreign currencies are collapsed together and we estimate a three-alternative choice model with $c = \{\text{eur ; other foreign currencies}\}$ and HUF as the baseline category. The mismatch indicator is constructed for the EUR only. As an alternative, we also test the model that places emphasis on the CHF as a speculative currency. In this case, the choice set becomes: $c = \{\text{chf ; other foreign currencies}\}$ and HUF. Since the share of debt denonominated in foreign currencies other than the EUR and the CHF has been limited in Hungary, we expect the two specifications to yield similar results.

The multinomial discrete choice models are estimated using the mixed logit procedure described in detail in Train (2003). The approach allows very flexible substitution patterns through the estimation of random rather than fixed parameters. Within each firm, the random terms are allowed to be correlated across alternatives, however, they are uncorrelated across firms: $\text{corr}(\omega_{ic}, \omega_{i'c'}) = \rho_{\omega_c,\omega_{c'}}$ for all c and c' if $i = i'$ and 0 otherwise.

Conditional on knowing the parameters of the model, the probability that firm i chooses currency c on a given choice occasion is given by McFadden's logit formula (eq. 1). The unconditional mixed logit probability is the integral of the conditional probability over all the possible parameter values, which depends on the density function of each of the random parameters. The estimation is carried out using maximum simulated likelihood technique (see Train (2003)).

As in the binomial case, we apply Mundlak's correction to both alternatives by including firm-level averages in the equations. Theoretically, it is possible to use a very general random coefficient specification by assuming that all coefficients (Ω_c, ϕ_c, ξ_c and the intercepts for all c) vary randomly. However, depending on the number of coefficients the estimation procedure becomes very complex as multiple integrals have to be solved (Train (2003)). In this paper, we assume only the intercepts to be random.[8]

[7] source: Eurostat Comext database. The latest available corresponding trade shares are (in 2015): 61 per cent to the eurozone and less than 1 per cent to Switzerland.

[8] The mixed logit procedure with an arbitrary combination of random and fixed parameters can also be applied to the binomial case. Assuming only the intercept to be random is equivalent to the random effects logit model described earlier. Although the estimation strategy of mixed logit models differs from that of the standard random effects model, the mixed logit procedure with random intercepts and the random effects logit model yield very similar results.

5 Estimation results

Table 3 summarises the main estimation results. The first two columns report the results for the binomial specification estimating the probability of choosing FX over the domestic currency using conditional (fixed effects) logit (column (1)) and Mundlak's correlated random effects logit (column (2)) regression techniques. In both cases, the coefficients of the matching measure are positive and highly significant. The probability of taking out an FX loan is thus higher as long as the firm's expected export revenues fully cover its foreign currency debt service expenses, which provides strong evidence to support the role of natural hedging incentives in firms' debt currency choice.

The mixed logit models with three possible alternatives provide a more accurate, albeit still imperfect, measure of currency matching. As explained in Section 4, two specifications are considered. First, the results presented in column (3) of Table 3 correspond to the case in which exports are all assumed to be invoiced in EUR and consequently, only the EUR-denominated debt is used for hedging purposes. Debt incurred in other foreign currencies (that are collapsed together) is the result of speculation or other unexplained motives. Second, column (4) reports the results for the case in which CHF is the only purely speculative currency and debt incurred in any other foreign currency may potentially be used for hedging purposes. The mismatch indicators are constructed accordingly.

Table 3: Estimation results

			Mixed logit with three alternatives	
	Fixed-effects logit	Random-effects logit	EUR, other foreign currencies (∼CHF) and HUF	CHF, other foreign currencies (∼EUR) and HUF
	(1)	(2)	(3)	(4)
Matching	0.296*** [0.0683]	0.288*** [0.0710]	0.716*** [0.114]	0.702*** [0.107]
$\text{corr}(\omega_{\text{eur}}, \omega_{\text{chf}})$			0.271*** [0.029]	0.319*** [0.032]
No. of obsevations.	27 505	40 130	120 390	120 390
No. of firms	2 713	7 297	7 297	7 297

*Notes: Each column of Table 3 shows the results of a separate regression. The first specification is a firm fixed effects logit. It includes all firm- and bank-level controls (both lagged) described in the Appendix, year dummies and a constant. The next column shows the results for the correlated random effects logit regression. In addition to the aforementioned controls, the regression also controls for the time-averages of the variables for each firm to implement Mundlak's correction. The last two columns collect results from mixed logit regressions with three alternatives. Here, we allow the constants in both choice equations to be randomly distributed across firms. The elements of the covariance matrix and the correlation between alternatives (i.e. between the random terms ω_{eur} and ω_{chf}) are calculated from the estimated lower-triangular matrix L, where matrix L is the Cholesky factorisation of the covariance matrix. The corresponding standard errors are computed using the delta method. *** Significant at 1%, ** significant at 5%, * significant at 10%.*

The two specifications yield similar results. In particular, both estimates reinforce the role of matching incentives in firms' currency choice and suggest that, as expected, results previously presented for the binomial case are mainly driven by matching in EUR.[9]

The positive and significant estimated covariance between the two foreign currency alternatives implies that firms that are more likely to choose one of the two foreign currencies are also more likely to choose the other. Theory (Appendix B) suggests that the substitution pattern between foreign currencies is affected by two distinct yet interacting factors: arbitrage and diversification. While our model does not allow us to disentangle the two factors, the results suggest that diversification – i.e. holding both EUR and CHF debt – is more advantageous than consistently choosing

[9]The point estimates for the parameters of the matching measure are lower for the binomial regressions than for the mixed logit models. These estimates are, however, not directly comparable. As is the case with any nonlinear probability model, the coefficients are identified only up to scale and therefore estimated parameters across various estimation methods and different sample of firms and periods cannot be naively compared.

one (the preferred) FX over the other. In other words, the average (or representative) firm seeks diversification.

We also check the robustness of our results to various alternative measures capturing firms' matching incentives. Re-estimating our baseline specification presented in column 3 of Table 3 using net exports (column 1 of Table 4) or future 12-months average export revenues (column 2) instead of the firm's past 12-months average export sales does not alter the results. In addition, we also re-estimate the model using a simpler, binary matching indicator variable that takes a value of 1 if the firm's debt repayment obligation denominated in foreign currency c ($L_{ij'c,t+1}$) is lower than or equal to its export revenues in the same foreign currency (X_{ict}) and 0 otherwise (column 3). This latter specification simply tests whether the firm has a higher probability of incurring new FX-denominated debt in the situation that its export revenues exceed its FX-denominated debt reimbursement obligations than in a mismatch situation. Results based on these alternative measures confirm our baseline findings.[10]

The remaining three columns in Table 4 explore potential heterogeneity with respect to firm and contract characteristics and possible changes in firms' matching behaviour after the start of the crisis. In particular, we let the parameter of the matching measure take different values for foreign firms (foreign ownership over 50 per cent; column 4), for short-loan contracts (1 year or less; column 5) and for the post-crisis period (2009-2011; column 6).

The significantly positive interaction term between the matching measure and the foreign firm dummy reveals that matching incentives play a somewhat more important role for foreign-owned firms than for domestic firms. This result is at odds with the hypothesis that foreign-owned firms, several of which are subsidiaries of foreign multinationals, may be less concerned about natural hedging as multinational companies can actively manage exchange rate risks at the corporate level. Furthermore, multinationals are also more likely to use financial hedging instruments such as spot, forward, futures and options markets to lower their foreign exchange risk exposure (Allayannis et al. (2012)). Contrary to these arguments, our results suggest that foreign firms more actively manage exchange rate risks via natural hedge measures as domestic firms.

Column 5 of Table 4 shows that currency matching is more of a concern when the contract is long-term. At the same time, we do not find evidence that the crisis has changed firms' matching

[10] In addition to the specifications presented in the paper, we also re-estimated the binary models (columns 1 and 2 of Table 3) and the alternative mixed logit models (columns 3 and 4 of Table 3) using the three alternative matching measures (net exports, forward-looking and the binary matching indicator). In all theses cases, the matching measure is positive and highly significant. We also performed several placebo mixed-logit regressions, in which we included the matching variable in the CHF equation instead of the EUR equation. We either used the same matching variable as before (export revenues minus EUR-denominated debt reimbursement obligations) or we constructed an alternative matching measure defined as the difference between export revenues and CHF-denominated debt reimbursement obligations. In these placebo regressions, the parameters of the matching variable are not statistically significant. All these regression results are not presented in this paper for reasons of brevity, but are available from the authors upon request.

Table 4: Robustness checks

	Net exports	Forward-looking	Dummy	Foreign cross-term	Short loan cross-term	Post-crisis dummy
	(1)	(2)	(3)	(4)	(5)	(6)
Matching indicator	0.514***	0.310***	0.208***	0.644***	0.829***	0.684***
	[0.083]	[0.079]	[0.060]	[0.119]	[0.131]	[0.128]
Matching × Foreign				0.291**		
				[0.134]		
Matching × Short loan					-0.177*	
					[0.098]	
Matching× Post-crisis						0.052
						[0.098]
corr$(\omega_{\text{eur}}, \omega_{\text{chf}})$	0.279***	0.294***	0.286***	0.268***	0.274***	0.272***
	[0.027]	[0.028]	[0.031]	[0.029]	[0.029]	[0.029]
No. of observations	120 390	120 390	120 390	120 390	120 390	120 390
No. of firms	7 297	7 297	7 297	7 297	7 297	7 297

*Notes: The table collects results of our baseline mixed logit model presented in column 3 of Table 3 using alternative matching measures (columns 1 to 3) and matching measures interacted with various dummy variables (columns 4 to 6). In the first specification (column 1), net exports are used for X_{ict} instead of export sales. The second column shows the results for the mismatch measure using firms' future 12-months average export sales instead of past values (column 2). In column 3, the matching measure is a binary indicator variable that takes the value of 1 if $X_{ict} - L_{ij'c,t+1} \geq 0$ and 0 otherwise. In the following columns, the matching measure is interacted with foreign ownership dummy (>50%, column 4), short-term contract dummy (≤ 1 year, column 5) and a post-crisis period dummy (2009-2011, column 6). All regressions include all firm- and bank-level controls (both lagged) described in the Appendix, alternative-specific year dummies and constant terms. In addition, the regressions control for the time-averages of all variables for each firm to implement Mundlak's correction. The elements of the covariance matrix and the correlation between alternatives (i.e. between the random terms ω_{eur} and ω_{chf}) are calculated from the estimated lower-triangular matrix L, where matrix L is the Cholesky factorisation of the covariance matrix. The corresponding standard errors are computed using the delta method. *** Significant at 1%, ** significant at 5%, * significant at 10%.*

behaviour. Although the crisis has led to a severe deterioration in the attractiveness of the CHF compared with both the local currency and the EUR – either because the expected financial gain from taking out CHF loans declined or because the perceived risks associated with bank loans denominated in CHF increased –, this effect is captured by the declining estimated alternative-specific year effects and did not alter the parameter of the matching measure.[11]

6 Matching or carry trade?

An important advantage of our modelling approach compared with those previously used in the literature is that our model allows us to perform a counterfactual analysis to isolate the effects of currency matching motives on proportion of the aggregate corporate debt denominated in FX. To do so, we first predict for all exporting firms and for all choice occasions the probability of choosing the EUR, the "other FX" ($\sim$CHF) or the HUF using the estimated baseline model presented in column 3 of Table 3 and the alternative specifications in Table 4. The firm-level expected values of the random terms (ω_{ic}) are approximated as suggested by Revelt and Train (2000) and the predictions are performed according to the multinomial logit formula in eq. (1). The weighted – by the size of the loan – yearly averages of these probabilities give the estimated aggregate currency shares of newly contracted bank loans. We then "switch off" the effects of currency matching on firms' debt denomination choice by setting the parameter of the matching measure to 0 for all observations and we predict the counterfactual currency shares of newly contracted corporate loans in the absence of matching motives. The weighted averages of these counterfactual probabilities correspond to each currency's share of new loans that would have resulted from speculation or other non-explained motives, i.e. if natural hedging strategy was irrelevant. The difference between the baseline predictions and the counterfactual currency shares represents the effect of matching on the aggregate shares.

Note that the effect of matching on the aggregate currency shares is a result of two opposing effects. For observations where the matching measure is positive – i.e. the firm's export revenues are higher than its debt reimbursement obligations denominated in FX – the currency matching strategy results in higher probability of choosing FX. In constrast, firms are less likely to take out an FX loan when they are already in a mismatch situation. The effect of matching on the aggregate currency shares of new loans depends on the size of these two opposing effects and the relative weights of the two groups of firms.

[11] This conclusion holds even if different random parameters (ω_{ic}) are estimated for the pre- and post-crisis periods that can be correlated both in time and between alternatives or if we restrict our estimation sample to firms contracting new debt in both periods. These results, together with the evolution of the estimated alternative-specific year effects are also available from the authors upon request.

Table 5 presents the results, separately for the period 2005-2008 (panel A) and 2009-2011 (panel B). The first column of the table shows the baseline predicted currency shares in total newly contracted debt in each currency using the estimated mixed logit model in column 3 of Table 3 (first rows in each panel) and the alternative specifications presented in Table 4 (rows 2 to 7). The last rows of panel A and B show the observed currency shares of newly contracted loans by exporters for the pre- and post-crisis period, respectively.

Although the model appears to moderately overestimate the share of EUR and – especially for the post-crisis period – underestimate the share of "other FX" ($\sim$CHF), overall the predicted currency shares are relatively close to the observed ones.

The second and the third columns of Table 5 show the estimated effect of matching in percentage points, separately for firms with negative or positive matching measures. According to our baseline specification, before the crisis, the currency matching strategy of firms that were already too much indebted compared to their export revenues reduced the share of debt in EUR by 1.5 percentage point. At the same time, in firms whose export revenues fully covered their FX debt repayment obligations arising from already existing contracts, matching resulted in an increase in the share of debt in EUR of 3.3 percentage points. Overall, if currency matching had not been part of firms' strategies, the share of the newly contracted debt by exporters that was in EUR would have been lower by 2.4 percentage points and that of the other FX currencies would have been higher by 0.6 percentage points. In terms of total FX debt, matching represents 1.8 per cent of the aggregate new debt subscribed by exporters before the crisis.

Table 5: Decomposition of currency choice (exporters only)

	Baseline prediction (1)		Matching effect X-L<0 (2)		X-L>=0 (3)		All exporters (4)	
	EUR	Other FX	EUR	Other FX	EUR	Other FX	EUR	Other FX
(A) 2005-2008								
Baseline	37.8	9.0	-1.5	0.2	3.3	-0.7	2.4	-0.6
Net export	37.8	8.8	-2.1	0.4	2.3	-0.5	-0.2	0.0
Forward-looking	37.7	8.9	-0.7	0.1	1.7	-0.4	1.2	-0.3
Dummy	37.4	9.0			3.0	-0.6	2.4	-0.4
Foreign cross-term	37.8	9.0	-1.5	0.2	3.7	-0.8	2.7	-0.6
Short loan cross-term	37.8	9.0	-1.6	0.2	3.6	-0.8	2.6	-0.6
Post-crisis cross-term	37.8	9.0	-1.5	0.2	3.1	-0.7	2.3	-0.5
Data	33.8	10.7						
(B) 2009-2011								
Baseline	44.3	3.4	-3.0	0.1	3.1	-0.2	1.7	-0.1
Net export	43.9	3.2	-2.5	0.3	2.1	-0.1	-0.7	0.1
Forward-looking	43.7	3.4	-1.4	0.1	1.6	-0.1	0.8	0.0
Dummy	43.5	3.4			3.0	-0.3	2.3	-0.3
Foreign cross-term	44.2	3.3	-3.0	0.1	3.5	-0.3	2.0	-0.2
Short loan cross-term	42.2	3.2	-3.0	0.2	3.3	-0.3	1.9	-0.2
Post-crisis cross-term	44.2	3.2	-3.1	0.1	3.2	-0.2	1.8	-0.1
Data	38.6	7.3						

Notes: the table presents the simulation results, as explained in the text, separately for the period 2005-2008 (panel A) and 2009-2011 (panel B). Column 1 shows the weighted averages of the predicted currency shares in total new debt using the estimated mixed logit model in column 3 of Table 3 (first rows in each panel) and the alternative specifications of Table 4 (rows 2 to 7). The last rows of panels A and B show the observed currency shares of newly contracted loans by exporters in the pre- and post-crisis period, respectively. Column 2 present the estimated effect of matching in percentage points for firms with negative matching measure, while column 3 shows the same results for firms with positive matching measure. Finally, column 4 presents the estimated matching effect for all exporters.

The other specifications give similar results. The lowest aggregate effect of matching is obtained for the specification in which net exports are used, rather than export sales. By definition, as net export revenues are lower than export sales for importing firms, the share of firms with a negative matching measure is higher than in our baseline specification. As a result, the negative effect of matching on the share of debt in EUR for firms already in a mismatch situation fully

counterbalances the positive matching effect for firms with a positive matching measure. While the specification using forward-looking export sales gives somewhat lower estimates for the effects of matching, adding foreign, short-loan or post-crisis cross-terms to the estimated equation does not seem to affect the results. Note that in the specification with binary matching indicator, which takes the value of zero if $X_{ict} - L_{ij'c,t+1} < 0$, the matching effect can be only assessed for those choice occasions when the firm's export revenues exceed its FX-denominated debt reimbursement obligations. For this group, the results are comparable to our baseline specification. Despite the fact that this model cannot capture the negative effect of matching for firms that are in a mismatch situation, the aggregate results for all exporters are close to our baseline results.

Since the start of the crisis, the slowdown in external demand and the depreciation of the HUF has made existing currency mismatches more pronounced. As a consequence, the demand for loan denominated in EUR has decreased among mismatched firms, which is reflected in the higher matching effect in absolute terms in comparison with the pre-crisis period (panel B of Table 5). The similarity of the results obtained using the baseline specification and the one with post-crisis cross-term suggests that firms' underlying matching behaviour has not changed since the start of the crisis. The stronger matching effect among mismatched firms is the result of the changing economic environment which has increased the stock of unhedged FX debt expressed in local currency. As a result, the share of EUR-denominated new debt related to matching among all exporting firms has decreased from 2.4 percentage points during the pre-crisis period to 1.7 percentage points during the period 2009-2011 (column 4 of Table 5).

Given that the share of debt contracted by exporters that was EUR-denominated was on average 33.8 per cent between 2005 and 2008 and 38.6 per cent between 2009 and 2011, the overall effect of currency matching on the aggregate currency shares seems rather limited: about 7.2 per cent of the overall corporate EUR-denominated debt contracted during the pre-crisis and 4.4 per cent during the post-crisis periods can be explained by matching motives. Assuming that non-exporters do not take natural hedging considerations into account, these figures represent less than 3 per cent of the aggregate (non-exporters included) new EUR-denominated bank loans underwritten during the period considered. In terms of total FX debt, less than 5 per cent contracted by exporters and less than 2 per cent of the total value of FX bank loans underwritten during the period between 2005 and 2011 can be explained by currency matching behaviour. Thus, most newly contracted FX debt is not related to natural hedging.[12]

[12]The effects of matching on the aggregate corporate debt (non-exporters included) is calculated as the share of the EUR or FX loans that can be attributed to matching among exporters multiplied by the share of the EUR or FX debt taken out by exporters: 39.7 per cent of the EUR debt before the crisis and 47.9 per cent of the EUR debt during the period 2009-2011; and 35.5 per cent of the total FX debt during the pre-crisis period and 48.9 per cent of the total FX debt during the post-crisis period.

7 Conclusion

Households indebted in FX naturally expose themselves to exchange rate risks. Conversely, firms with export revenues can also use FX debt to reduce or eliminate their exposure to exchange rate variations. While a large body of empirical research documents a significant positive correlation between the share of FX debt in firms' balance sheets and a proxy for the sensitivity of firms' revenues to exchange rate fluctuations, such as export shares or an indicator of tradability, there is little rigorous empirical evidence on the importance of matching motives in firms' currency-of-denomination decisions. Furthermore, there has been no clear understanding whether natural hedging motivation or other factors such as the interest rate differential is the key driver of firms' currency choices.

This paper investigates firms' willingness to match the currency composition of their assets and liabilities and their incentives to deviate from perfect matching in the presence of multiple available foreign currency loans. We rely on Hungarian corporate loan data and estimate discrete choice models in which firms choose the currency denomination of their loans.

Results show that the probability of borrowing in FX is strongly correlated with a currency matching measure defined as the difference between the firm's export revenues and its debt repayment obligations denominated in FX. This finding is robust across various model specifications, which provides strong evidence to support the role of currency matching incentives in firms' currency choice. Matching motivation is even stronger for foreign companies and for long-term loans. However, our counterfactual simulations suggest that natural hedging is not the primary motivation for firms to choose FX: it explains only less than 5 per cent of the overall new corporate FX loans contracted by exporters and less than 2 per cent of the aggregate new FX bank loans. In addition, our results suggest that the benefits from diversification outweigh the perceived carry trade opportunities between EUR and CHF, the two major foreign currencies in Hungary.

While our model allows us to isolate the effects of matching motives on firms' currency choice, we do not directly explain the underlying reasons why firms deviate from the pure natural hedging strategy. One obvious candidate is the interest rate differential and thus firms' carry trade strategies, yet other explanations may also exist. The existing literature proposes a few other explanations for firms' FX choice. However, none of these alternative explanations seems relevant for Hungary. For instance, Shapiro (1984) shows that in some countries, such as Sweden, the tax law encourages firms to incur FX debt by making foreign exchange losses on FX debt immediately tax deductible, while taxes on foreign exchange gains are deferred until realised. On the other hand, if the exchange losses (gains) on the principal of the FX debt are tax deductible (taxable) at the same rate as the local corporate income tax, such as is the case in Hungary, the firm is indifferent to whether it borrows in FX or in local currency. Other papers concentrate on the financing decisions of multinational

firms. Multinationals may have incentives to locate their debt in the country with the highest tax rate (see e.g. Hodder and Senbet (1990)) or may choose the country and the currency in which the debt is incurred depending on legal barriers (Jorion and Schwartz (1986)) or the costs of gathering information (Hietala (1989)). These theories go little way to explaining the FX borrowing of many domestic firms from local commercial banks.

Other explanations may exist, but, apart from exploiting interest rate differentials, we are not aware of any convincing evidence or theory that could explain why FX debt accounts for such a high proportion of total debt in Hungary or in other similar countries. Most likely, the largest share of corporate FX debt, at least in Hungary, corresponds to open carry trade positions held by non-financial corporations.

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Appendix

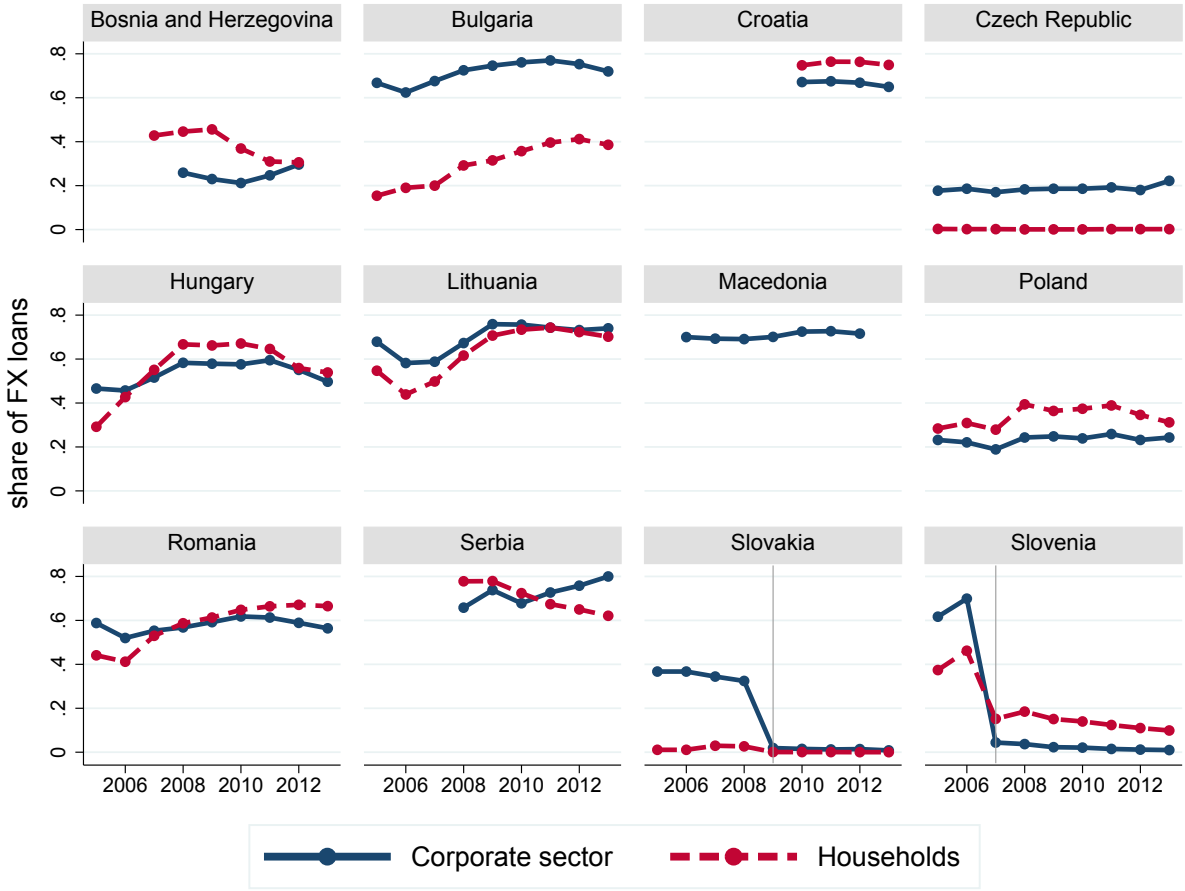
A Foreign currency debt in CEE countries

In many Central and Eastern European (CEE) countries, lending in foreign currencies to both households and firms has been the norm rather than the exception. As shown in Figure 2, FX-denominated bank loans accounted for at least 20 per cent of total corporate debt in the twelve countries considered. Bulgaria, Croatia, Macedonia and Slovenia recorded the highest pre-crisis shares, but FX was also dominant in Hungary, Lithuania and Romania. FX lending to the household sector displays a large heterogeneity across countries. It has been mostly prevalent in Croatia, Hungary, Lithuania, Romania and Serbia, while virtually zero in the Czech Republic and Slovakia.

The financial crisis originating from the US subprime mortgage meltdown rapidly escalated to a global scale and brought to the fore the vulnerability of several CEE countries heavily indebted in FX. The high level of bank lending denominated in FX was less of a concern in Slovenia and Slovakia: by the time of the crisis emerged, Slovenia had already adopted the EUR, while Slovakia joined the eurozone at the beginning of 2009. Similarly, the currency board in Bulgaria and the fixed exchange rate regime in Lithuania (and, later, the introduction of the EUR) insulated firms and households from adverse exchange rate shocks. In other countries, however, the weakening of the exchange rate first increased firms' debt burden expressed in terms of the local currency then, as a consequence, forced firms to adjust their balance sheets.

Hungary was one of the most affected economies in the region. The country entered the crisis with a combination of a high budget deficit, large current account imbalances and an over-leveraged private sector with a significant exchange rate risk exposure. The crisis led to the depreciation of the HUF and quickly turned the FX debt previously considered as advantageous into a serious trouble for numerous firms and households heavily indebted in FX. The fact that post-crisis performance was poorest among FX borrowers is also confirmed by Endresz and Harasztosi (2014), who demonstrate that FX lending increased investment rates prior to the crisis, while balance sheet effects triggered by the depreciation decreased the investment of firms with FX loans. The authors also show that both effects are likely to be heterogeneous, being more pronounced for firms with liquidity constraints. Likewise, Ranciere et al. (2010) show that before the crisis FX borrowing and lower interest rates benefited small domestic firms via a relaxing of credit constraints, while no effect was found for larger firms.

Figure 2: FX shares, 2005-2013



Notes: The figure shows the share of outstanding liabilities in the domestic financial sector (excl. central banks) denominated in foreign currency held by non-financial corporations and households. For Bosnia, Croatia, Macedonia, Slovakia and Slovenia, the data come from the Central Bank's Financial Stability report. For Bulgaria, the Czech Republic, Hungary, Poland and Romania, the data come from the ECB's Balance Sheet Items (BSI) statistics. Vertical lines show the dates of entry into the eurozone: 2007 for Slovenia and 2009 for Slovakia. Lithuania also joined the eurozone in 2015.

B The optimal debt currency portfolio

To illustrate the effect of exchange rate fluctuations on firms' borrowing decisions, firms' optimal debt currency composition is derived from a simple two-period model. We abstract from some realistic aspects of firms' investment strategies and concentrate on the main features of their financing decisions that are relevant for our purposes. The firm's decision is modelled as a mean-variance optimisation problem of modern portfolio theory, in which risk averse investors seek to maximise

the expected terminal wealth for a given level of risk captured by the variance of the expected cash flows.[13]

The basic structure of our framework is similar to that of several previous studies (e.g. Thomas (1985); Ize and Yeyati (2003); Luca and Petrova (2008); Bleakley and Cowan (2009); Basso et al. (2011)) with two important distinctions. First, firms may already hold an initial debt in period 0 when the decision takes place, in which case the amount of remaining debt at the end of period 0 and its interest are reimbursed at the end of period 1. Second, we allow firms to choose – in addition to the local currency – among several foreign currencies in which to borrow.[14] We start with the general case of any arbitrary number of funding currencies, then we look at the simple case with only two possible foreign currencies in more detail.[15]

In period 0, the potential borrowing firm has an initial wealth $w_0 > 0$ that can be invested and an initial debt $B_0 \geq 0$ expressed in local currency. A fraction γ_c of the initial debt is denominated in foreign currency $c = \{1, ..., C\}$. Management decides on the investment strategy, contracts new loans ($B_1 > 0$) to finance the part of the investment that exceeds w_0 and chooses the currency composition of the new loans. The share of the newly contracted debt that is denominated in foreign currency c is denoted by β_c. In period 1, the project's cash outflow from the initial investment of amount $K_1 = B_1 + w_0$ is given by $F(K_1)$, where the function F is assumed strictly increasing and concave in K.[16] A fraction α_c of the total output from the project is exported and invoiced in currency c. Both the previous debt B_0 and the new debt B_1 are reimbursed with the accrued interest at the end of period 1. The firm's terminal net wealth w_1 is given by:

$$w_1 = \left(\sum_{c=1}^{C} \alpha_c e_{1c} + (1 - \sum_{c=1}^{C} \alpha_c)\right) F(K_1) - \left(\sum_{c=1}^{C} \gamma_c e_{1c}(1 + i_0^c) + (1 - \sum_{c=1}^{C} \gamma_c)(1 + i_0^d)\right) B_0 - \left(\sum_{c=1}^{C} \beta_c e_{1c}(1 + i_1^c) + (1 - \sum_{c=1}^{C} \beta_c)(1 + i_1^d)\right) B_1 \quad (2)$$

[13]The mean-variance optimisation was introduced in the seminal paper by Markowitz (1952), which is considered as the foundation of modern portfolio theory. The concept was later rationalised by Levy and Markowitz (1979), who showed that any twice differentiable von Neumann - Morgenstern utility function can be approximated by a mean-variance utility function. Even though the framework has been relentlessly criticized, the mean-variance technique has a strong intuitive appeal and still constitutes the cornerstone of portfolio theory (Dybvig and Ross (2003)).

[14]The model is general regarding the form of debt financing, it applies equally to corporate bonds, commercial papers and bank loans. However, in the empirical part of this paper, we only concentrate on bank loans. The markets for corporate bonds and commercial papers are underdeveloped in Hungary. (See Fig 1. of https://www.imf.org/external/pubs/ft/wp/2008/wp08103.pdf)

[15]As the number of relevant debt issuing currencies is generally limited, firms debt currency allocation problem usually does not require high-dimensional portfolio optimisation. In practice, at most only a few currencies are taken into consideration. One or two currencies generally dominate the FX loan market in all developing and transition countries. In non-European countries, the USD has been the predominant debt issuance currency. Liabilities in emerging Europe have mainly been denominated in EUR and in CHF, the share of other currencies (mainly USD) has been limited.

[16]Function F also takes into account capital depreciation.

Today's exchange rates e_{0c} are normalised to 1 and we assume that $E\left[e_{1c}\right] = 1$ for all c. The domestic interest rates of the previous contract and the new contract in local currency are given by i_0^d and i_1^d, respectively. The total costs of borrowing in FX (i_0^c and i_1^c) equal the foreign interest rates plus the expected rate of depreciation of the home currency. We assume that the interest rates i_0^d and i_0^c are fixed by an already existing contract. For some reason, the uncovered interest rate parity (UIP) between the local currency and any of the foreign currencies may not hold, i.e. the market interest rate in a particular FX may be lower than that of the local currency ($i^d \geq i^c$).

Obviously, any risk-neutral firm would maximise its expected terminal wealth by choosing to incur the full amount of debt B_1 in the "cheapest" currency at the minimum interest rate. In reality, however, the optimal debt portfolio takes into account how investors are averse to risk. The firm's decision is modelled as a mean-variance optimisation problem of modern portfolio theory in which risk averse investors seek to maximise the expected terminal wealth for a given level of risk captured by the variance of the expected cash flows.

For simplicity, we assume that the future exchange rate is the only source of uncertainty, and influences both firms' export revenues and their FX debt reimbursement expressed in local currency. From eq. (2), the expected variance of the portfolio is given by:

$$\begin{aligned} \mathrm{V}[w_1] = \sum_{c=1}^{C} \sum_{c'=1}^{C} \left[\alpha_c F(K_1) - \gamma_c(1+i_0^c)B_0 - \beta_c(1+i_1^c)B_1\right] \times \\ \left[\alpha_{c'} F(K_1) - \gamma_{c'}(1+i_0^{c'})B_0 - \beta_{c'}(1+i_1^{c'})B_1\right] \rho_{e_c,e_{c'}} \sigma_{e_c} \sigma_{e_{c'}} \end{aligned} \tag{3}$$

where $\sigma_{e_c} > 0$ is the standard deviation of the exchange rate of currency c vis-à-vis the local currency and $\rho_{e_c,e_{c'}}$ is the correlation coefficient between the exchange rates of c and c'. It is reasonable to assume that $0 \leq \rho_{e_c,e_{c'}} < 1$ for all $c' \neq c$.

According to the mean-variance approach, the firm maximises its objective function characterised by the weighted combination of expected terminal wealth and its expected variance:

$$\max_{K_1,\beta} \left\{ \mathrm{E}[w_1] - \frac{\theta}{2} \mathrm{V}[w_1] \right\} \tag{4}$$

where $\theta > 0$ is the Arrow-Pratt measure of constant absolute risk aversion. The expected terminal wealth is given by eq. (2) by setting $e_{1c} = 1$ for all c and the expected variance is presented in eq. (3).[17]

It is immediately apparent from eq. (3) that the minimal variance portfolio is achieved with $\beta_c = \beta_c^M = \left(\alpha_{\mathrm{c}} F(K_1) - \gamma_c(1+i_0^c)B_0\right) / \left((1+i_1^c)B_1\right)$ for all c, i.e. when the currency matching is

[17] For presentation convenience, positivity constraints – $\beta_c \geq 0$ for all c and $(1 - \sum_{c=1}^{C} \beta_c) \geq 0$ – are ignored. If any of the constraints are binding, a complementary slackness condition should be applied, which implies a corner solution for one or several currency shares.

perfect. In this case, the expected variance of the portfolio is zero. The expected terminal wealth with the perfect matching portfolio is a straightforward benchmark that any firm with any degree of risk aversion can achieve. If the firm is not fully risk-averse ($\theta < \infty$) and at least one foreign interest rate i_1^c is lower than i_1^d, it is possible to achieve higher expected profits by moving along the efficiency frontier, i.e. choosing a risky (volatile) debt portfolio with higher expected terminal wealth.

To see this, let us solve the maximisation problem (4) w.r.t. β_c for a given (optimal) K_1. The optimal currency shares are given by the following system of first order equations:

$$\frac{\partial}{\partial \beta_c} = B_1 G_c - \theta B_1^2 \left(\sum_{c'=1}^{C} (\beta_{c'} - \beta_{c'}^M) \rho_{e_c, e_{c'}} \sigma_c \sigma_{c'} \right) = 0, \forall c \tag{5}$$

where $G_c = \left(\left(1 + i_1^d\right) - \left(1 + i_1^c\right) \right) \geq 0$ is the expected financial gain from contracting one unit of debt in currency c instead of the local currency and $\sigma_c = \sigma_{e_c} \left(1 + i_1^c\right)$ is the corresponding standard deviation of the reimbursement obligation.

Equation (5) can be solved using standard linear algebra techniques. Using matrix notations, the solution is given by:

$$\hat{\beta} = (1/(\theta B_1)) V^{-1} G + \beta^M \tag{6}$$

where $\hat{\beta}$ and β^M are $C \times 1$ vectors with elements $\hat{\beta}_c$ and β_c^M, respectively, G is a $C \times 1$ vector of G_c's and V^{-1} is the $C \times C$ inverse of the variance-covariance matrix (a.k.a. concentration matrix or precision matrix) with elements $\rho_{e_c, e_{c'}} \sigma_c \sigma_{c'}$. The optimal portfolio is thus the sum of a standard Markowitz portfolio (the speculative component) and a hedge term represented by the perfect matching portfolio.

It is easy to see that – for a given K_1 – the expected excess financial gain over the perfect matching debt portfolio is $\mathrm{E}[\hat{w}_1] - \mathrm{E}[w_1 \left| \beta = \beta^M \right.] = (1/\theta)\, G^T V^{-1} G \geq 0$ and the variance of the portfolio is $\mathrm{V}[\hat{w}_1] = (1/\theta^2) G^T V^{-1} G \geq 0$. That is, if the firm is not fully risk-averse ($\theta < \infty$) and if there is at least one "cheaper" FX in the set of possibilities ($i_1^c < i_1^d$ for at least one c), the firm is willing to take some risk in exchange for higher expected future profits. Indeed, the firm will be taking on a carry trade position by exploiting perceived arbitrage opportunities between funding currencies.

Although the mathematical expressions for $\hat{\beta}_c$ shares become quite complex as the number of potential currencies increases, the properties of the Markowitz portfolio selection model are well-known from the financial literature. In a world with only one FX, the optimal allocation between the risky FX loan and the risk-free domestic loan is a simple trade-off between the additional gain

(G) that the investor generates by increasing the FX share above the perfect matching level and the utility lost generated by the higher variance $(\theta\sigma^2)$.[18]

The possibility of contracting debt in more than one FX brings in two additional considerations: diversification and possible arbitrage opportunities between foreign currencies. According to equation (6), the relative "mismatch shares" $\tilde{\beta}_c/\tilde{\beta}_{c'} = (\hat{\beta}_c - \beta_c^M)/(\hat{\beta}_{c'} - \beta_{c'}^M)$ for all c and c' are independent of the degree of risk aversion and the amount of borrowed funds. In other words, firms set their diversification strategies and the relative allocation between foreign currencies according to their beliefs about relative gains and volatilities associated with the various alternatives and the correlation between the exchange rates, independently of their risk preferences.

To probe deeper into how firms choose how to allocate their debt among multiple foreign currencies, let us consider the simple case with two available foreign currencies denoted by, for example, eur and chf. The optimal weights are given by:

$$\begin{cases} \hat{\beta}_{\text{eur}} - \beta_{\text{eur}}^M = \tilde{\beta}_{\text{eur}} = \frac{G_{\text{eur}}}{\theta\sigma_{\text{eur}}^2 B_1} \frac{1-\rho_{e_{\text{eur}},e_{\text{chf}}}(1/\psi)}{1-\rho_{e_{\text{eur}},e_{\text{chf}}}^2} \\ \hat{\beta}_{\text{chf}} - \beta_{\text{chf}}^M = \tilde{\beta}_{\text{chf}} = \frac{G_{\text{chf}}}{\theta\sigma_{\text{chf}}^2 B_1} \frac{1-\rho_{e_{\text{eur}},e_{\text{chf}}}\psi}{1-\rho_{e_{\text{eur}},e_{\text{chf}}}^2} \end{cases} \tag{7}$$

The firm's perception of arbitrage opportunities is captured by $\psi = (G_{\text{eur}}/\sigma_{\text{eur}})/(G_{\text{chf}}/\sigma_{\text{chf}})$, which is equal to 1 if the certainty equivalent foreign interest rates (or gains) are equal, and consequently, the firm has no arbitrage incentive between the two foreign currencies.[19] In the absence of arbitrage opportunities, the optimal currency shares simplify to $\tilde{\beta}_c = (G_c/(\theta\sigma_c^2 B_1))/(1 + \rho_{e_{\text{eur}},e_{\text{chf}}}),\ c = \{\text{eur ; chf}\}$. The shares of debt in both FX are strictly discreasing with the correaltion between the two exchange rates. In fact, the additional FX share above β_c^M is twice as large in the case where the correlation is zero than when $\rho_{e_{\text{eur}},e_{\text{chf}}} \to 1$. This result emerges from the principle of Markowitz diversification, which states that as the correlation between the returns on assets that are combined in a portfolio decreases, so does the variance of that portfolio. The same logic applies to optimal debt portfolio choices. The optimising firm can thus increase the share of its risky portfolio and thereby increase expected wealth while maintaining risks within acceptable limits.

If $\psi \neq 1$, an additional trade-off arises between taking advantage of arbitrage opportunities and diversification. Without loss of generality (as the problem is symmetrical), let us assume that

[18] According to eq. (6), the optimal $\hat{\beta}$ is also negatively correlated with the amount of borrowed fund B_1. In fact, in this framework, Markowitz's equations determine the optimal *level* of FX borrowing. It follows that a firm with constant absolute risk aversion (θ) contracts a fixed amount of risky FX debt, independently of the total amount of borrowing and the firm's initial wealth. This unrealistic implication of utility functions with constant absolute risk aversion is largely criticised in the financial literature. Nevertheless, this unpleasant property of the basic mean-variance framework does not alter the main messages of the paper. See e.g. Dybvig and Ross (2003) for alternative utility functions used in the literature.

[19] If $\psi = 1$, restricting $\beta_{\text{eur}} = \beta_{\text{eur}}^M$ or $\beta_{\text{chf}} = \beta_{\text{chf}}^M$ and solving the problem for the other FX share generates, in both cases, the same utility for the investor.

$\psi < 1$, i.e. chf is preferred to eur. For low values of $\rho_{e_{\text{eur}},e_{\text{chf}}}$, the benefit from diversification is relatively high, while the carry-trade between the two foreign currencies is risky. As the correlation between the two exchange rates increases, diversification benefits become smaller and smaller and firms increasingly take advantage of the more attractive currency. Overall, $\hat{\beta}_{\text{eur}}$ is strictly decreasing with $\rho_{e_{\text{eur}},e_{\text{chf}}}$, while $\hat{\beta}_{\text{chf}}$ exhibits a U-shaped relationship with $\rho_{e_{\text{eur}},e_{\text{chf}}}$ with a minimum at $\rho_{e_{\text{eur}},e_{\text{chf}}} = \psi^{-1}\left(1-\sqrt{1-\psi^2}\right)$.

Although the firm's management is supposed to have a clear preference for chf – because either the interest rate and/or the volatility of the exchange rate is lower –, the firm still maintains a higher debt share than required by matching even in the less attractive foreign currency (eur) as long as $\rho_{e_{\text{eur}},e_{\text{chf}}} < \psi$. Above this threshold, the relative attractiveness of chf outweighs the diversification benefits. If the positive constraint for β_{eur} is not binding (i.e. if $\beta^M_{\text{eur}} > 0$), the firm is even willing to sacrifice the security provided by perfect matching and to lower $\hat{\beta}_{\text{eur}}$ below β^M_{eur}.

Finally, the full solution of the maximisation problem in eq. (4) requires solving for the optimal K_1. The F.O.C. w.r.t. K_1 yields:

$$\begin{aligned} F'(K_1) = &\left(\sum_{c=1}^{C}\beta_c(1+i_1^c) + (1-\sum_{c=1}^{C}\beta_c)(1+i_1^d)\right) \\ +\theta B_1 &\left(\sum_{c=1}^{C}\sum_{c'=1}^{C}\left(\beta_c - \tfrac{\alpha_c F'(K_1)}{1+i_1^c}\right)\left(\beta_{c'} - \beta^M_{c'}\right)\rho_{e_c,e_{c'}}\sigma_c\sigma_{c'}\right) \end{aligned} \tag{8}$$

The optimality condition for K_1 equates the expected marginal product of capital to the user cost (represented by the first term of the right hand side of eq. (8)) plus a marginal risk premium (second term). In line with the real option investment theory, the marginal product has to be greater than its marginal cost in the presence of uncertainty (Pindyck (1991)). Uncertainty increases the value of waiting (call option) and decreases the propensity to invest now relative to what would be suggested by a simple net present value rule. In this simple framework, combining equations (5) and (8) gives: $F'(K_1) = (1+i_1^d)/(1+\sum_{c=1}^{C}\alpha_c G_c/(1+i_1^c))$. Accordingly, the propensity to invest is unaffected by the possibility of borrowing in FX for non-exporting risk-averse investors.

C Descriptive statistics of the variables

Table 6: Descriptive statistics of the variables

	All firms		Exporters*	
Definition of the variable	mean	st. d.	mean	st. d.
Matching measures				
Baseline			0.243	0.346
Net exports			-0.020	0.421
Forward-looking			0.273	0.385
Dummy			0.128	0.335
Other contract level variables				
Short contract dummy (duration is one year or less)	0.312	0.463	0.431	0.495
Loan size / total assets (in logs)	4.682	1.575	4.081	1.834
Firm level variables				
Employment (in logs)	2.576	1.388	4.017	1.591
Foreign ownership dummy (over 50%)	0.059	0.236	0.223	0.416
Importer dummy	0.187	0.390	0.823	0.382
Exports share in sales	0.048	0.173	0.308	0.335
Firms' real capital (in logs)	0.354	0.231	0.357	0.205
Current assets / total assets	0.613	0.261	0.616	0.220
Ttotal assets (in logs)	11.600	1.776	13.457	1.201
Profits / total assets	0.026	0.281	0.029	0.092
Bank level variables				
Foreign ownership dummy (over 50%)	0.948	0.211	0.935	0.238
Ttotal assets (in logs)	14.275	0.985	14.142	0.978
Bank capital ratio	0.088	0.034	0.084	0.035
Bank liquidity ratio	0.151	0.076	0.155	0.087
Profits / total assets	0.006	0.019	0.005	0.022
Doubtful loan ratio	0.587	0.046	0.583	0.045

*Notes: The table provides descriptive statistics on the variables of the dataset used in the estimations, separately for all firms and for exporters. The table separates the variables related to the firms and those related to the banks providing the loans. *Estimation sample for exporters.*

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